World Energy Outlook 2021

Energy security and the risk of disorderly change

By design, the scenarios in this *Outlook* describe smooth, orderly processes of change. In practice, however, energy transitions can be volatile and disjointed affairs, characterised by competing interests and stop-go policies. As the world makes its much-needed way towards net zero emissions, there is an ever-present risk of mismatches between energy supply and demand as a result of a lack of appropriate investment signals, insufficient technological progress, poorly designed policies or bottlenecks arising from a lack of infrastructure. In the APS, countries undertake clean energy transitions at different speeds, raising the risk of tensions in global trade and constraints on technology transfer. In the NZE, potential new hazards could arise alongside the rise of clean energy.

Investment mismatches

Energy transitions bring about a major shift in the primary energy mix away from carbon-intensive fuels towards low-carbon energy sources. Although the share of fossil fuels in the mix has remained at around 80% over several decades, it declines to around 50% by 2050 in the APS and collapses to just over 20% in the NZE. Lower demand for fossil fuels, and in particular for oil and natural gas, ultimately reduces some traditional energy security hazards, but it cannot be taken for granted that the journey will be a smooth one. Our projections highlight the huge uncertainty over the trajectory for future demand. If there are no further changes in today's policy settings, as in the STEPS, oil demand in 2050 remains above 100 mb/d. By contrast, if the world single-mindedly pursues a 1.5 °C stabilisation objective, then oil demand falls to 24 mb/d in the same year. The comparable range for natural gas is between 5 100 bcm in the STEPS and 1 750 bcm in the NZE.

These variations come with dramatically different implications for investment. The declines in oil and gas demand in the NZE are sufficiently steep that no new field developments are required: continued spending to maintain production from existing assets, and reduce the associated emissions, amounts to an annual average of USD 210 billion between 2020 and 2050 in the NZE. In the STEPS, on the other hand, the annual amount required for investment is around USD 680 billion, well above current levels. If companies and investors misread demand trends amid uncertainty about the future, there is a risk of either market tightening or of over investment leading to underutilised and stranded assets.

Investment in clean energy in the Stated Policies and Net Zero Scenario, 2016-2030 **Open**

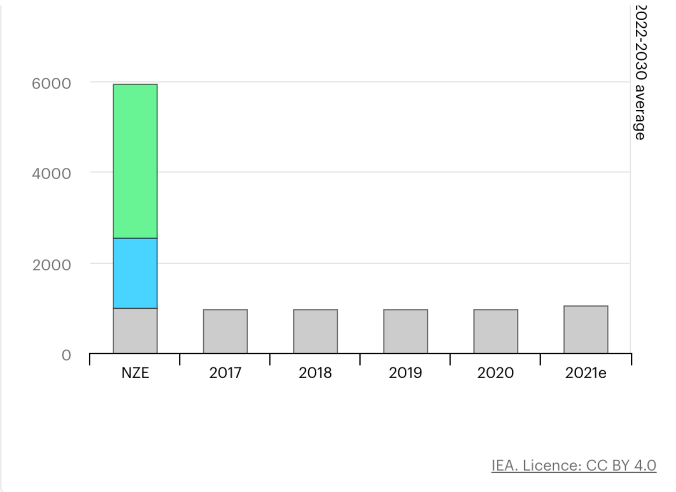
billion USD (2020)

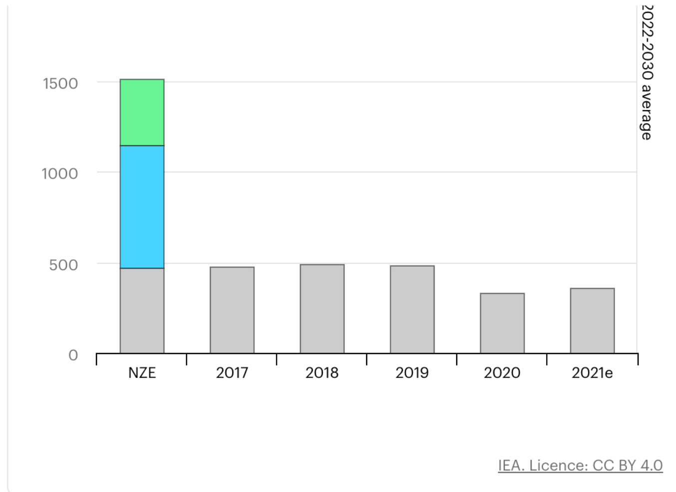
8000

Investment in oil and gas production in the Stated Policies and Net Zero Scenario, 2016-2030 **Open**

billion USD (2020)

2000





The fact that no new oil and natural gas fields are required in the NZE does not mean that limiting investment in new fields will lead to the energy transition outcomes in this scenario. If demand remains at higher levels, this would result in tight supply in the years ahead, raising the risks of higher and more volatile prices. It is not clear that higher prices would trigger supply responses to the same extent as in the past. A strong policy push to reduce oil and gas demand in line with the trajectory envisaged in the NZE therefore is key to achieving deep reductions in emissions and minimising the risk of market tightening.

Market design and infrastructure in increasingly integrated systems

Many of the new energy security challenges in a decarbonising world arise in the power sector as societies come to depend more on electricity for their energy needs. Across all scenarios the share of variable renewables in electricity generation rises to reach 40-70% by 2050 (and even more in some regions), far above the global average of just under 10% today. Wind and solar PV generation varies with the weather as well as with the time of day and year, and this can cause sudden changes to generation patterns on a daily or weekly basis. A large share of seasonal energy demand is also transferred onto the power system through the increasing use of electric heating and cooling equipment. Electricity storage, demand-side response and dispatchable low emissions sources of power are essential to meet flexibility requirements in clean energy transitions.

Managing imbalances between supply and demand, especially over longer timeframes, without resorting to emissions-intensive fuels requires a fundamental transformation of how energy systems operate. Today's energy sector is in essence a series of interlinked but largely independent delivery channels for fuels, heat and electricity to consumers. The energy system of the future consists of a much more complex web of interactions between solid, liquid and gaseous fuels, and electricity. In the NZE by 2050, around 40% of primary energy is converted at least twice before reaching end-users. Energy travels through batteries and electrolysers, undergoes conversions from electricity to heat or fuels, and back again. Such conversion processes are essential to provide the system flexibility needed to match the supply of variable renewables and demand for electricity at least cost. The need for such flexibility in the NZE is considerable: utility-scale battery storage increases from less than 20 GW in 2020 to over 3 000 GW by 2050, and there are millions of behind-the-meter enablers of flexibility, in the form of smart meters, EVs and charging infrastructure.

Key indicators of energy system change by scenario, 2020-2050

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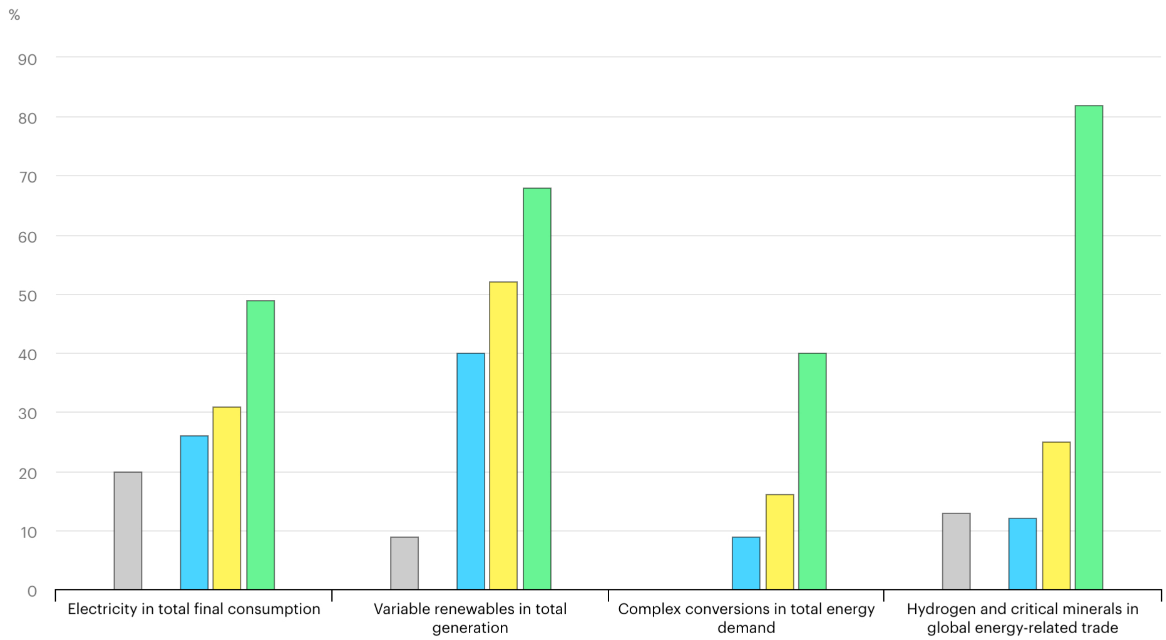

2020 | 2050 - Stated Policies Scenario | 2050 - Announced Pledges Scenario | 2050 - Net Zero Scenario

Notes

A more complex energy system, with electrification at its core, raises important questions about the future of natural gas infrastructure, which in many parts of the world plays an important role in meeting seasonal demand for heating as well as short-term peaks in power generation. Current underground gas storage facilities have a capacity of 420 bcm per year – equivalent to more than half of the world's residential space heating demand. This buffer for households relying on gas for heating is not easily replicated by the electricity system. Gas power plants are also a mainstay of today's electricity security because of their ability to flexibly ramp up and down in response to changes in variable renewable output or peaks in demand. In the APS, even though generation on an annual basis declines in the United States and the European Union, the peak of generation from gas-fired power plants in those regions is 10-15% higher in 2030 than in 2020. This underscores the need for market designs that recognise the flexibility value of existing infrastructure even as the focus turns to developing innovative options that can replicate the services that natural gas provides (including low-carbon hydrogen).

Ultimately, secure transitions require careful sequencing to ensure that change in one area is complemented by change elsewhere. A reduction in oil and gas investment requires a surge in capital spending on low emissions fuels and technologies. Bans or limitations on the use of gas boilers or ICE vehicles only work if there are low-carbon alternatives that can deliver the same energy services, ideally at a similar or lower cost to consumers. Minimising the contribution of unabated coal and gas power plants to electricity supply requires lower carbon sources of flexibility in their place. These changes bring opportunities to make use of parts of today's fuel supply system in new ways: for example, there is scope for the supply, transport and storage of hydrogen to piggyback on existing gas pipelines and storage. The key point is that policy makers need to understand not just the value of energy, but also the value of the system's overall capacity to provide it when needed.

The world's energy infrastructure faces increasing physical risks from a changing climate. We estimate that around a quarter of the world's electricity networks face a high risk of destructive cyclone winds, while over 10% of dispatchable generation fleets and coastal refineries are prone to severe coastal flooding and a third of freshwater-cooled thermal power plants are located in high water stress areas. These risks are set to increase over time, highlighting the urgent need to enhance the resilience of energy systems to climate change.

Shifting geopolitics of energy security

Clean energy transitions are set to bring about a major change in the energy trade patterns that have long been dominated by fossil fuels. The rising importance of critical minerals and low-carbon hydrogen means that their combined share in global energy-related trade doubles to 25% by 2050 in the APS. In the NZE, the share rises further to 80% by 2050 as the value of fossil fuels trade plunges, completely overturning the current dynamics of international energy-related trade.

Energy geopolitics are typically associated with oil and gas. However, clean energy technologies are not immune from geopolitical hazards. The production and trade of critical minerals provide a case in point. Overall mineral requirements for clean energy technologies almost triple between today and 2050 in the STEPS, and up to sixfold in the NZE. However, today's supply and investment plans point to a risk of supply lagging behind projected demand in the NZE. Higher or more volatile prices for critical minerals could make global progress towards a clean energy future slower or more costly. Recent price rallies for critical minerals illustrate the point: all other things being equal, they could make solar panels, wind turbines, EV batteries and grid lines 5-15% more expensive, with ripple effects on the costs of transitions.

The challenges are compounded by a lack of geographical diversity in critical mineral extraction and processing operations. In many cases, the supply of critical minerals is concentrated in a smaller number of countries than is the case for oil and natural gas. This is inevitably a source of concern because it means that supply chains for solar panels, wind turbines and batteries using imported materials could quickly be affected by regulatory changes, trade restrictions or even political instability in a small number of countries. Early attention from policy makers is required to develop a comprehensive approach to mineral security that encompasses measures to scale up investment and promote technology innovation together with a strong focus on recycling, supply chain resilience and sustainability.

The NZE also sees the emergence of inter-regional hydrogen trade (including trade in hydrogen-based fuels such as ammonia), with regions that possess abundant low cost production potential exporting to those with more limited production options. Hydrogen trade grows to around USD 100 billion by 2050 in the APS, higher than the value of current international coal trade, and to USD 300 billion in the NZE. However, there is a question mark over how infrastructure and market norms will develop as demand increases. Hazards could arise from a lack of co-ordination between potential exporters and importers or bottlenecks in infrastructure and equipment manufacturing capacity. Careful co-ordination and dialogue will be essential to bring forward new supply chains in a timely way.

Natural gas import dependency in developing economies in Asia and level of supply concentration by scenario, 2020, 2030 and 2050

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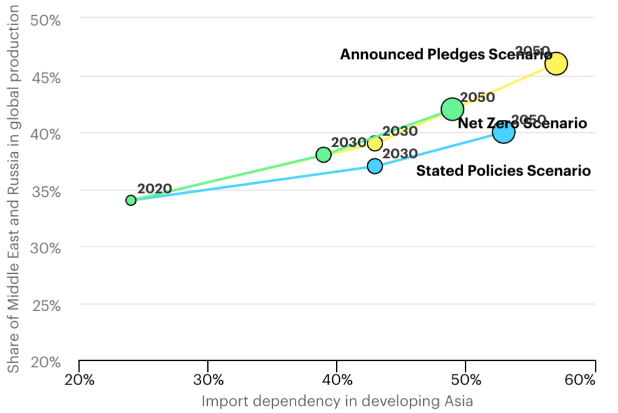

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Stated Policies Scenario
Announced Pledges Scenario
Net Zero Scenario

Oil import dependency in developing economies in Asia and level of supply concentration by scenario, 2020, 2030 and 2050

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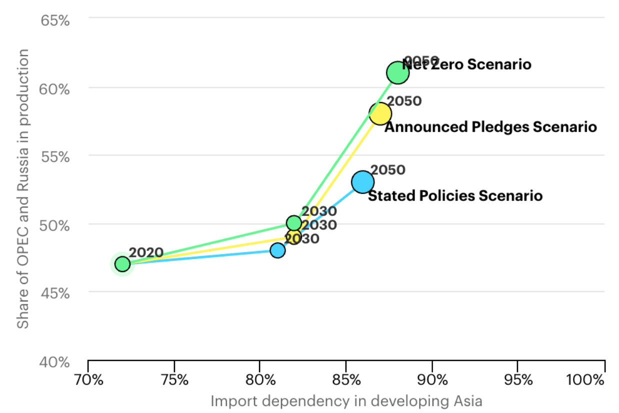

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Stated Policies Scenario
Announced Pledges Scenario
Net Zero Scenario

While new dimensions of energy geopolitics arise, the traditional significance of trade in hydrocarbons does not vanish. Oil and gas supplies in the APS and NZE become increasingly concentrated in a small number of low cost producers. The share of Organization of the Petroleum Exporting Countries (OPEC) members and the Russian Federation (hereafter Russia) in global oil production rises considerably from 47% today to 61% in 2050 in the NZE. Many of the producer economies poised to take a larger share in future supply nevertheless face the prospect of significantly falling hydrocarbon income as overall demand falls. For the moment, these producers remain poorly prepared for transitions, with limited progress on economic and energy diversification, raising the possibility of a bumpy and volatile ride. Meanwhile, import dependency on fossil fuels in developing economies in Asia remains high in all scenarios, leading to further concentration of trade flows between the Middle East and Asia. This suggests that Asian importers will continue to be exposed to risks arising from physical or geopolitical events in the Middle East or accidents near trade chokepoints, underscoring the need for vigilance on the security of supply even in a world with contracting fossil fuel demand.

Next

Fuels: old and new